MRI

Effect of Controlled Burning on Soil Erodibility by Wind

Final Test Report

For
Radian International

MRI Project No. 110056

May 16, 2001

Midwest Research Institute

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For
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P.O. Box 201088
Austin, Texas 78720-1088

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Preface

This report was prepared by Midwest Research Institute (MRI) for Radian International under Purchase Order No 803991 In this report, MRI presents the methodology and results of the wind erodibility testing of burned and unburned grassland at the Rocky Flats Environmental Technology Site, located northwest of Denver, Colorado

The work was conducted in MRI's Applied Engineering Division Dr Chatten Cowherd, who served as the project leader for MRI, coordinated the preparation of this report Other MRI technical staff who contributed to the program were Mary Ann Grelinger (data acquisition) and Courtney Kies (data reduction)

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May 16, 2001

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Section 1. Introduction

The purpose of this study was to determine the impact of a prescribed vegetative burn on the potential for wind-generated particulate emissions from soils and vegetation at the Rocky Flats Environmental Technology Site northwest of Denver A controlled 50-acre test burn took place on April 6, 2000 Wind tunnel tests were performed by Midwest Research Institute (MRI) on representative portions of the test-burn area (Figure 1) and also on an adjacent unburned grassy area within the Rocky Flats site

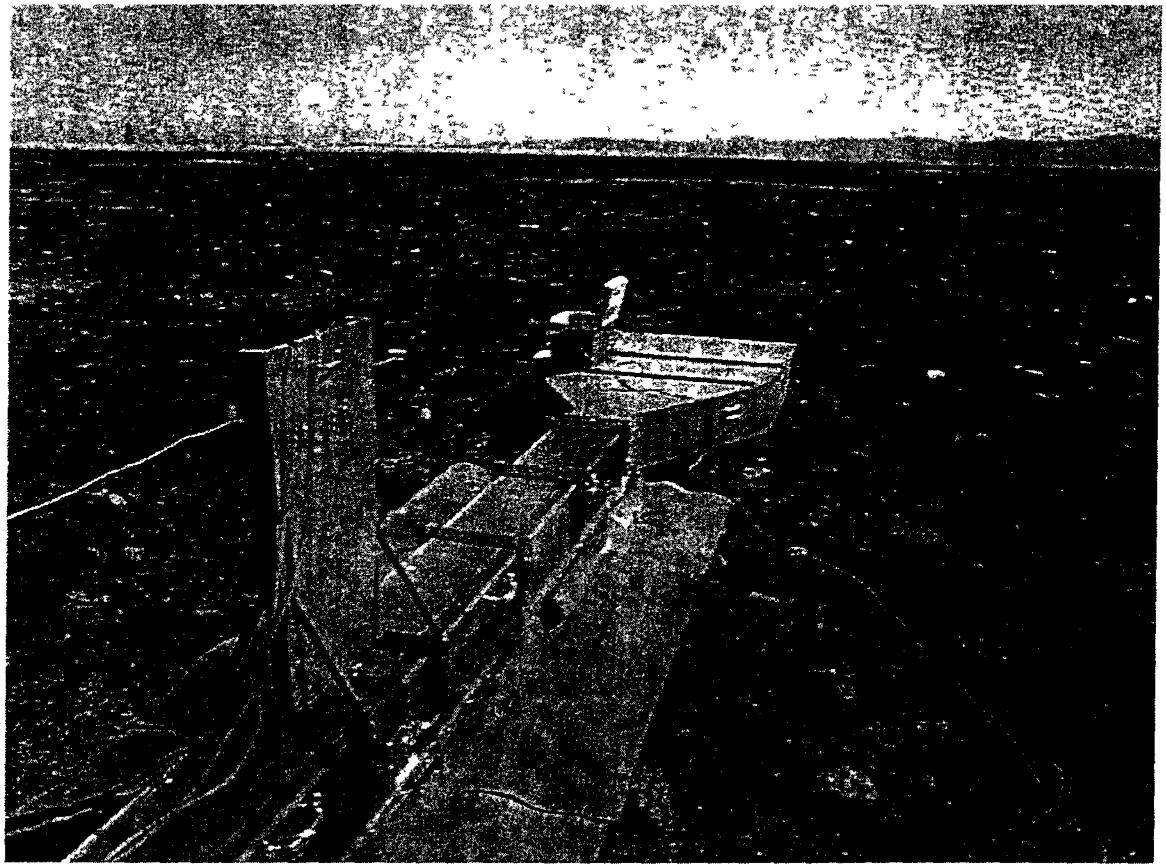

Figure 1 MRI Wind Tunnel on Prescribed Burn Area at Rocky Flats, April 2000

The testing was initiated the day after the controlled burn of the grassland Subsequent tests over a period of three months (April to June 2000) were conducted to evaluate the length of time it takes for new vegetation to restore soil protection against high wind events Test objectives were also to determine (a) whether a clearly evident threshold velocity exists for the onset of wind erosion, (b) how dust emissions increase from one wind speed plateau to the next, and (c) how the emissions decay in time at a given wind speed

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The primary test device used in the evaluation was MRI's portable reference wind tunnel with a time-integrating air sampler for collection of PM-10 (particles less than or equal to 10 µm in aerodynamic diameter) Two TSI DustTRAK monitors were connected to the wind tunnel to provide real-time concentrations of PM-10 and PM-2 5 in the tunnel effluent Carbon analysis of filters used during the field testing was done to separate the soil component from the ash component of the PM-10 collected In addition to field testing, laboratory dustiness tests were run on bulk surface soil samples from burned areas to characterize the soil texture, including the PM-10 and PM-2 5 dustiness, and the natural mitigative effect of soil moisture

This report describes (a) the types of equipment and the procedures that were used in field testing at Rocky Flats and laboratory testing at MRI and Desert Research Institute, and (b) the results of testing along with an analysis of field and laboratory test results The report is organized as follows

- Section 2 describes the equipment and procedures used for field sampling of the controlled burn area and for laboratory tests of surface soil samples and PM-10 filters from the wind tunnel testing
- Section 3 presents the wind tunnel test results together with an analysis and interpretation of the test results
- Section 4 presents the laboratory test results together with an analysis and interpretation of the test results
- Section 5 concludes the report with a summary of the test results and the conclusions that can be drawn from the results
- Section 6 lists the literature references

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Section 2. Test Methods

Field tests were performed to observe the effect of wind speed on the particulate emissions generated from unburned and burned grassland areas at Rocky Flats. The impact of the controlled vegetative burn on the soil emission potential was evaluated over a three-month period using MRI's portable reference wind tunnel along with two TSI DustTRAK monitors.

The MRI portable pull-through wind tunnel, as described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites* (USEPA, 1989), was used in performing the field study of wind-generated emissions from the controlled burn area. This MRI reference wind tunnel (Figure 2) features all of the required design and operating characteristics, including the equipment for extracting isokinetic samples of wind generated particulate matter for measurement of mass emissions and particle size distribution. It is powered by a gasoline engine with direct mechanical linkage to the primary blower, which pulls the airflow through the tunnel.

In operating the wind tunnel, the open-floored test section is placed directly over the surface to be tested. Air is drawn through the tunnel at controlled velocities. The exit air stream from the test section passes through a circular duct fitted with a sampling probe near the downstream end. Air is drawn through the probe by a high-volume sampling train that separates total airborne particulate (TP) emissions into two particle size fractions: particles larger than 10 µm in aerodynamic diameter and particles smaller than 10 µm in aerodynamic diameter (PM-10). Note that TP contains particles as large as several hundred microns in diameter that are released from the test surface under high wind conditions. Interchangeable probe tips are sized to provide for isokinetic sampling, so that large particle sampling biases do not occur.

A high-volume ambient air sampler is operated near the inlet of the wind tunnel to provide for measurement and subtraction of the contribution of the ambient background particulate level. By sampling under light ambient wind conditions, background interferences from upwind erosion sources can be minimized.

The wind tunnel method relies on a straightforward mass balance technique for calculation of emission rate and no assumptions about plume configuration are required. This technique provides for precise study of the wind erosion process on specific test surfaces for a wide range of wind speeds. Previous wind erosion studies using the MRI reference wind tunnel have led to the EPA recommended emission factors presented in *Compilation of Air Pollutant Emission Factors (USEPA, 2000)*.

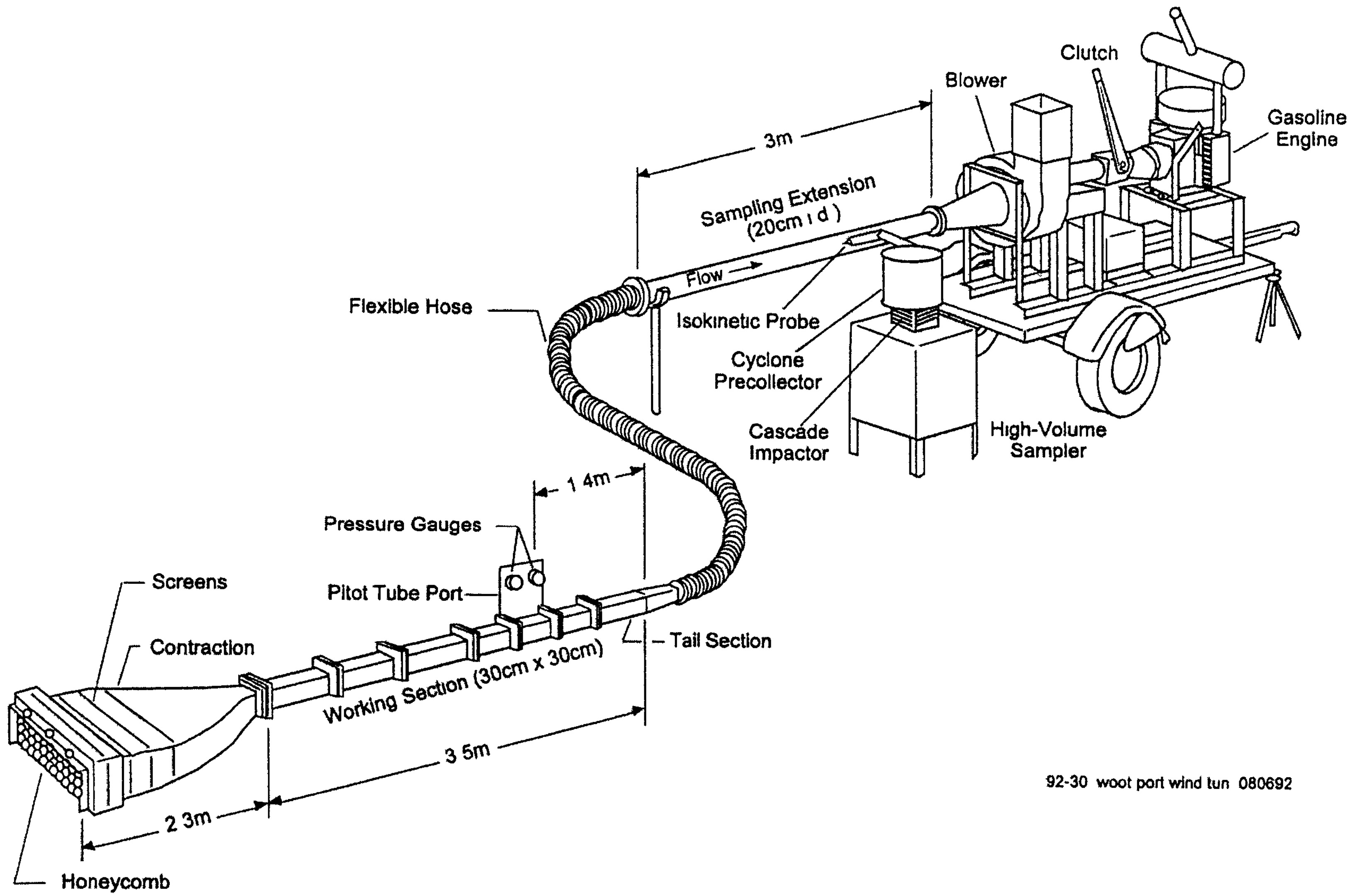

Figure 2. MRI Portable Wind Tunnel

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2.1 Wind Tunnel Sampling Equipment

The MRI reference wind tunnel (Figure 2) is identical in design to that developed by Gillette (Gillette, 1978) but is nearly twice as large It consists of a two-dimensional 5 1 contraction section, an open-floored working section with a 30 cm by 30 cm cross-section, and a roughly conical diffuser The test area of this tunnel (30 cm by 3 1 m) provides for its use on rougher surfaces The tunnel centerline airflow is adjustable up to an approximate maximum speed of 19 m/s (40 mph), as measured by a pitot tube at the downstream end of the test section The equivalent wind speed at a reference height of 10 m above the ground is approximately two to three times the speed at the tunnel centerline

Although the portable wind tunnel does not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnel simulates the smaller scales of atmospheric turbulence It is the smaller scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to the particle entrainment mechanisms The MRI reference wind tunnel has been used to develop USEPA AP-42 emission factors for industrial wind erosion (Cowherd, 1988)

The wind speed profiles near the test surface (tunnel floor) and the walls of the tunnel have been shown to follow a logarithmic distribution (Gillette, 1978)

$$u(z) = \frac{u^*}{0\ 4} \ln \frac{z}{z_0} \qquad (1)$$

where u = wind speed, cm/s
u^* = friction velocity, cm/s
z = height above test surface, cm
z_o = roughness height, cm

The friction velocity, which is a measure of wind shear at the erodible surface, characterizes the capacity of the wind to cause surface particle movement As indicated from Equation 1, the wind velocity at any fixed height above the surface (but below the centerline of the wind tunnel) is proportional to the friction velocity The "micro-scale" roughness height of each test surface is determined by extrapolation of the logarithmic wind speed profile near the surface to where $u = 0$

An emissions sampling module (referred to in Figure 2 as the sampling extension) provides for representative extraction and aerodynamic sizing of particulate emissions generated by wind erosion The sampling module is located between the tunnel outlet hose and the fan inlet The particulate sampling train, which is operated at 68 m^3/h (40 acfm), consists of a tapered probe, cyclone precollector, glass fiber backup filter, and high-volume motor The sampling intake is pointed into the air stream, and the sampling velocity is adjusted to the approaching air speed by fitting the intake with a nozzle of appropriate size

When operated at 68 m^3/h (40 cfm), the cyclone has a nominal cutpoint of 10 μm aerodynamic diameter, based on laboratory calibration (Baxter et al , 1986) Thus the particulate fraction that penetrates the cyclone constitutes PM-10

A pitot tube is used to measure the centerline (CL) wind speed in the sampling extension, upstream of the point where the sampling probe is installed The volumetric flow rate through the wind tunnel is determined from a published relationship (Ower and Pankhurst, 1969) between the centerline (maximum) velocity in a circular duct and the average velocity, as a function of Reynolds' number Because the ratio of the centerline wind speed in the sampling extension to the centerline wind speed in the working section is nearly independent of flow rate, the ratio can be used to determine isokinetic sampling conditions for any flow rate in the tunnel

A portable high-volume air sampler with an open-faced glass fiber filter is operated on top of the tunnel inlet section to measure background levels of total suspended particulate matter (TSP) The aerodynamic cutoff diameter of TSP is usually assigned a value of 30 μm aerodynamic diameter The filter is vertically oriented, parallel to the tunnel inlet face Approximately half of the mass collected on the filter is assumed to be PM-10 The sampler is operated at 68 m^3/h (40 cfm)

2.2 Wind Tunnel Sampling Procedure

Prior to each test series, the working section of the tunnel is placed directly on the selected test surface To prevent air infiltration under the sides of the open-floored section, the rubberized skirts, attached to the bottom edges of the tunnel sides, are stretched out on the surface adjacent to the test surface Rubber inner tubes filled with sand are laid along the skirts to assure a tight seal

With the tunnel in place, the airflow is gradually increased to the threshold for the onset of wind erosion, as determined by visual observation of migration of coarse particles, and then reduced slightly At the sub-threshold flow, a wind speed profile is measured and a surface roughness height is determined In the absence of a clearly evident threshold velocity, the wind speed profile is measured at a tunnel centerline wind speed of approximately 9 m/s (20 mph)

The measured micro-scale roughness height allows for conversion of the tunnel centerline wind speed to the equivalent friction velocity and to the equivalent wind speed at a standard 10-m height, using the logarithmic wind speed profile If the terrain roughness (rolling hills, vegetation, etc) is much larger than the microscale roughness of the test plot, a separate area-wide roughness height reflecting the larger terrain features is used to convert the tunnel centerline wind speed to the equivalent wind speed at a standard 10-m height

For test surfaces that are found to have a well-defined threshold velocity, sampling is initiated just after the tunnel centerline wind speed reaches the first prescribed super-threshold level corresponding to the desired friction velocity or wind speed corrected to a height of 10 m After the prescribed sampling period, the flow is shut off and the particulate samples (cyclone catch and glass fiber backup filter) are removed

At the end of each test, the sampling train is disassembled and taken to the field instrument van and the collected samples of dust emissions are carefully placed in protective containers For transfer of samples to a laboratory setting, high-volume filters are placed in individual protective envelopes or in specially designed carrier cases Dust is transferred from the cyclone precollector by brushing it into a tared clear, resealable plastic pouch Alternatively, the cyclone catch can be sieved using a standard 325 sieve (45 µm pore size) The sieved cyclone catch when recombined with the PM-10 mass from the backup filter, represents total suspended particulate matter (TSP), approximately PM-30

Dust samples from the field tests are returned to an environmentally controlled laboratory for gravimetric analysis Glass fiber filters are conditioned at constant temperature (23°C ± 1°C) and relative humidity (45% ± 5%) for 24 h prior to weighing (the same conditioning procedure as used before tare weighing) The particulate catch from the cyclone precollector is weighed in the tared pouch

The raw test data that are recorded include the following

- Site code and description
- Test date, run number, and type of test
- Sample IDs (filters, cyclone catches, surface soils)
- Start time and sampling duration
- Threshold wind speed at tunnel centerline
- Subthreshold wind speed profile from which microscale roughness height is determined
- Operating wind speeds at tunnel centerline and at centerline of sampling tube
- Sampling module flow rate
- Ambient meteorology (wind speed and direction, temperature, barometric pressure)

2.3 Interpretation of Wind Tunnel Results

Because wind erosion is an avalanching process, it is reasonable to assume that the loss rate from the surface is proportional to the amount of erodible material remaining

$$\frac{dM}{dt} = -kM \quad (2)$$

where M = quantity of erodible material present on the surface at any time, g/m^2
k = proportionality constant, s^{-1}
t = cumulative erosion time, s

Integration of Equation 2 yields

$$M = M_o\, e^{-kt} \tag{3}$$

where M_o = erosion potential, i e, quantity of erodible material present on the surface before the onset of erosion, g/m^2

The loss of erodible material (g/m^2) from the exposed surface area during a test is calculated as follows

$$L = \frac{CQt}{A} \tag{4}$$

where C = average particulate concentration in tunnel exit stream (after subtraction of background concentration), g/m^3
Q = tunnel flow rate, m^3/s
A = exposed test surface area (0 918 m^2 for the reference wind tunnel)

Alternatively, the erosion potential can be directly calculated from the filter net mass (after correction for background)

Whenever a surface is tested at sequentially increasing wind speeds, the measured losses from the lower speeds are added to the losses at the next higher speed and so on This reflects the hypothesis that, if the lower speeds had not been tested beforehand, correspondingly greater losses would have occurred at the higher speeds

Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored A disturbance is defined as an action that results in the exposure of fresh surface material On a soil surface, this would occur whenever soil is either added to or removed from the old surface, or whenever surface material is turned over to a depth exceeding the size of the largest pieces of aggregate present in the soil

In summary, the calculated test results for each test surface and maximum wind speed include

- Roughness height (microscale) from extrapolated subthreshold velocity profile
- Friction velocity from measured centerline wind speed and roughness height, using Equation 1

- Equivalent wind speed at reference 10-m height from measured centerline wind speed and roughness height, using Equation 1
- Erosion potential (for "limited reservoir" surfaces) equivalent to the cumulative particle mass loss at a particular wind speed

2.4 DustTRAK Monitoring

Continuous monitoring of particulate concentration in the emission sampling module provides for a much greater level of detail in tracking the dynamics of the wind erosion process In the case of the subject study, two portable DustTRAK Aerosol Monitors (TSI, Inc , St Paul, Minnesota) continuously sampled air between the cyclone and the backup filter for the purpose of tracking the PM-10 and PM-2 5 concentrations in the tunnel effluent

The DustTRAK monitor is a portable, battery-operated instrument that gives real-time measurements and has a built-in data logger It weighs 3 3 lb and uses four C cells The instrument, as originally configured, samples PM-10, but can be fitted with a Dorr-Oliver nylon cyclone for industrial hygiene sampling (~3 5 μm cutpoint), or impactors for PM-2 5 and PM-1 sampling

The operating principle of the DustTRAK is based on 90° light scattering Light scattering (deflected) by local variations in refractive index is caused by the presence of dispersed species whose size is comparable to the wavelength of the incident light The theoretical detection efficiency based on Mie light scattering theory (developed in 1908) peaks at about 0 2-0 3 μm and gradually decreases for larger particle sizes A pump draws aerosol into the optics chamber where either solid or liquid particles are detected A laser diode light source, along with a solid-state photo detector, ensures greater stability and longevity The specially designed sheath air system is used to isolate the aerosol in the chamber, keeping the optics clean and reducing maintenance The instrument design gives measurements of particle concentrations from 0 001 to 200 mg/m^3 (Note that the instrument comes precalibrated to indicate mass concentration in mg/m^3 using Arizona road dust as the calibration reference)

The DustTRAK has two basic modes of operation a survey mode and a logging mode The survey mode displays real-time aerosol concentration measurements in mg/m^3 The logging mode functions similar to the survey mode with the added feature that the measurements are stored at programmable intervals for trending and reporting using the TrakPro Data Analysis Software

Once data has been logged by the monitor (30,000 data points can be recorded using 3 logging modes), the DustTRAK software can retrieve the information for a more comprehensive analysis, including maxima, minima, and averages for the entire sampling period or any user-selected interval The PC software also has a graphing capability that allows the comparison of PM-10 and PM-2 5 concentrations, assuming two monitors are available (one with a PM-2 5 impactor inlet) and simultaneous sampling occurs

The DustTRAK PM-10 monitor is calibrated against the actual PM-10 mass collected on the back-up filter of the wind tunnel effluent sampling train during a given test run This calibration entails an integration of the real-time DustTRAK PM-10 concentration profile (versus time) and calculation of the average DustTRAK PM-10 concentration for comparison to the average PM-10 concentration calculated from the net PM-10 mass collected on the back-up filter below the cyclone

Use of the DustTRAK monitors provides for a more comprehensive analysis of surface erodibility, especially appropriate to the study surfaces that do not have a well defined wind erosion threshold velocity On the burned vegetative surfaces at Rocky Flats, there are multiple contributors to wind generated particulate emissions (a) the bulk soil with the usual protection afforded by consolidation, (b) settled surface dust that is trapped by the vegetation, and (c) the vegetation itself The particle releases from these reservoirs are all driven by different mechanisms, each with a different wind speed dependence

Thus, the approach taken in this study was (a) to expose each test surface to a well defined time history of increasing wind speeds, and (b) to monitor continuously the PM-10 and PM-2 5 concentrations in the tunnel effluent Specifically, the wind speed was increased in increments of 2 m/s (5 mph) up to the capacity of the wind tunnel as follows

Wind Speed at Tunnel CL (mph)	Start Time (min sec)	Duration (min sec)
5	0 00	2 00
10	2 00	2 00
15	4 00	2 00
20	6 00	4 00
25	10 00	4 00
30	14 00	4 00
35	18 00	4 00
40	22 00	4 00

Typically, each time the wind speed was increased, a concentration spike was observed Furthermore, upon each successive increase, the peak value of the spike increased and the rate of decay decreased For centerline wind speeds at or above 20 mph, the duration of sampling was increased to a minimum of 4 min to allow additional time for the spike to decay Time integration generates erosion mass increments that when added together yield cumulative erosion potentials for PM-10 and PM-2 5 as a function of wind speed

An example of the concentration spikes that occur during wind tunnel testing can be seen in Figure 3 The length of time for the emissions to decay to a background level can also be seen

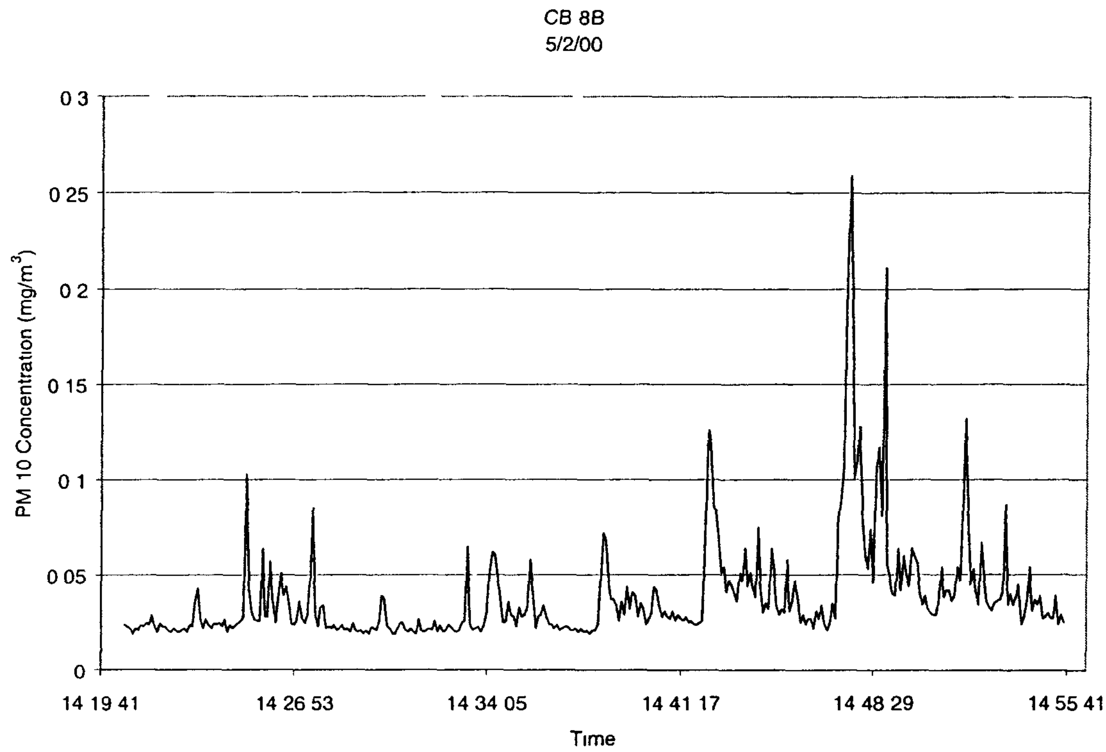

Figure 3. DustTRAK Graph for Run CB-8B

2.5 Surface Soil Sampling

In April and May 2000, six subareas in the controlled burn area were sampled for surface soil The sample collected from each subarea consisted of a composite of 5 to 8 incremental samples Each incremental sample was collected from a soil area of about 500 cm^2 between burnt vegetative stubble The soil samples were collected to a depth of approximately 1 cm to 1 5 cm using a whiskbroom and a dustpan The six areas from which composite samples were collected were judged to be representative of the wind tunnel test areas

2.6 Surface Soil Dustiness Testing

The MRI Dustiness Test Chamber (DTC) is a laboratory device used to determine the tendency of finely divided bulk materials (e g , soils, powders) to release fine particles

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(Cowherd et al , 1989) Within the chamber shown in Figure 4, the particles generated from controlled pouring of material are captured on an overhead filter with a sampling rate of 5 L/min The dustiness test method was originally developed to provide EPA with measures of "dustiness potential" and to quantify the important parameters affecting dustiness, including moisture content and material texture The DTC has also been used in several studies of contaminated materials to determine the partitioning of contaminants in the fine particle component

The DTC was adapted to collect PM-10 and PM-2 5 samples for determination of source emission profiles for receptor modeling For this purpose, size-selective inlets (Figure 4) were fitted to the sampling intake

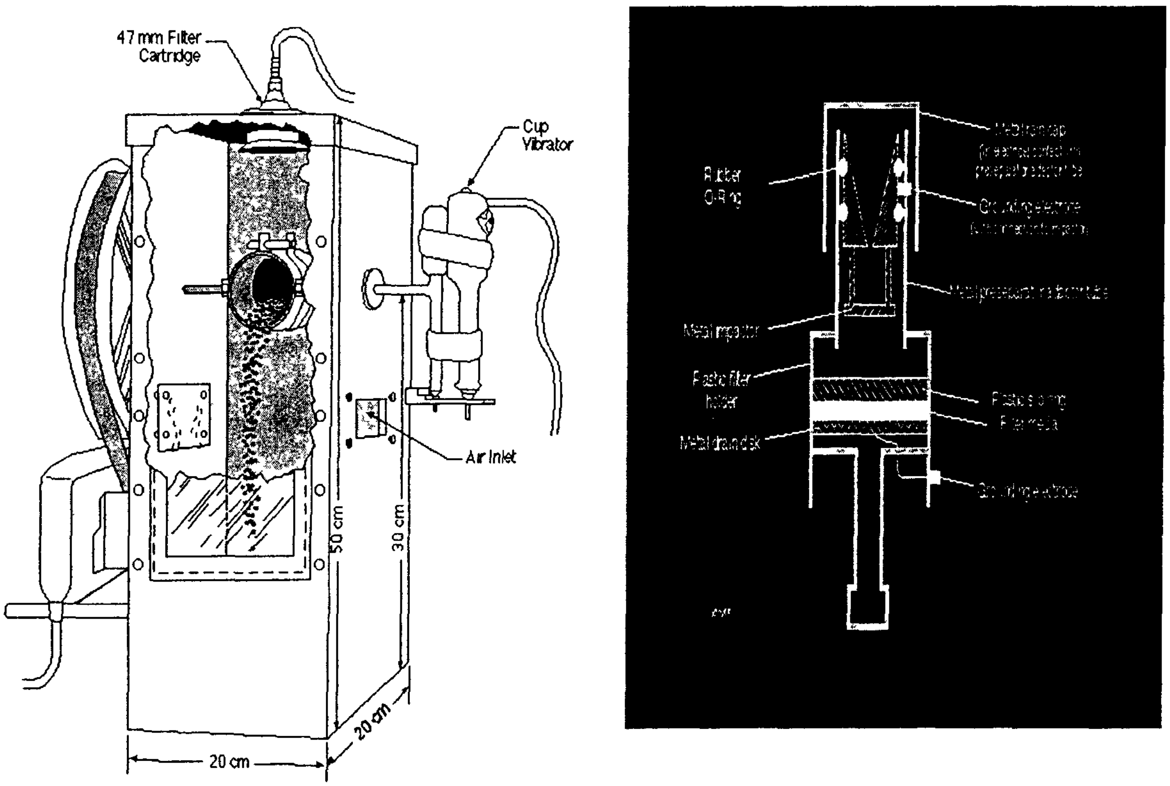

Figure 4. MRI Dustiness Test Chamber and Impactor Assembly (Inverted)

The following steps represent a typical test scenario for sampling particulate matter (PM) suspended during the pouring of material in the DTC

- Characterize the test material for moisture content (from weight loss upon oven drying)
- Install a clean tare weighed filter in the DTC
- Record the mass of material to be poured in the chamber

- Pour the test material and evacuate the chamber at 5 0 L/min for 10 min
- Analyze the filter gravimetrically and record the final filter weight

The net weight of PM caught on the filter (final filter weight minus tare weight) is divided by the mass of material poured to calculate the mass emission rate in units of mg of dust per kg of material poured This quantity is defined as the dustiness index of the test material

2.7 Carbon Analysis of PM-10 Filters

To quantify the ash contribution to the PM-10 mass produced in the wind tunnel testing, elemental carbon (EC) and organic carbon (OC) analysis were performed by Desert Research Institute (DRI) on sections of the 8-in by 10-in quartz fiber filters used in the wind tunnel testing and blank field and laboratory filters The analysis method was Thermal/Optical Reflectance (TOR), as described by Watson and Chow (1994)

The TOR method has been adapted by DRI from Huntzicker et al (1982) for the quantification of organic and elemental carbon in PM deposited on quartz filters In the DRI method (Chow et al , 1993), filter mass is volatilized in several temperature ramping steps Volatilization temperatures range from ambient to 550°C in pure helium atmosphere, then from 550°C and 800°C in a 2 percent oxygen and 98 percent helium mixture The carbon that evolves at each temperature is converted to methane and quantified with a flame ionization detector

Associated with the thermal evolution of carbon, the optical reflectance from the deposited mass on the filter is monitored As the temperature increases in the pure helium atmosphere, the organic material is pyrolized and reflectance typically decreases When oxygen is added at the higher temperatures, reflectance increases as the light-absorbing "black" elemental carbon is combusted and removed

Organic carbon is defined as that carbon which is volatilized prior to reattainment of the original reflectance—i e , carbon that does not absorb light at the wavelength of 632 8 nm Elemental carbon is defined as the carbon that is volatilized after the original reflectance has been attained—i e , light-absorbing carbon

Section 3. Results of Field Tests

Field tests of the prescribed burn area were performed over one-week periods beginning April 7, May 2, and June 19, 2000 Figure 5 shows the MRI wind tunnel during a prescribed burn area test During each test the wind tunnel was moved three times over the test area, to collect additional particulate on the back-up filter and improve the detection and precision of the PM-10 erosion potential

Figure 5 Wind Erosion Testing at Rocky Flats Prescribed Burn Area (April 2000)

The wind tunnel tests were performed at incrementally increasing tunnel centerline wind speeds The wind speed increments were 2 m/s (5 mph) at the centerline, up to the capacity of the wind tunnel The "peak" PM-10 and PM-2 5 concentration values (6-sec averages) for each wind speed plateau are observable in the "real-time" concentration histories, recorded by the DustTRAK monitors

The test site parameters for each of the wind tunnel test runs are provided in Table 1 The surface roughness heights for the test runs were determined by fitting vertical profiles of wind speed in the test section of the wind tunnel to logarithmic functions An average roughness height was calculated for each test series, for purposes of calculating friction velocities and 10-m equivalent wind speeds

Table 1. Test Site Parameters

Date	Surface characteristics	Run no	Start time	Duration (min)	Ambient wind speed (mph)/ direction	Temperature (°F)	Barometric pressure (in Hg)	Relative humidity (%)	Surface roughness height (cm)
4/7/00	Burned Area (Plot 1)	CB-1A	11 30	44	6 N	51	24 40	43	1 22
		CB-1B	15 32	39	11 NE	51	24 43	35	1 02
		CB-1C	16 40	43	1 SE	59	24 40	25	0 30
4/8/00	Burned Area (Plot 2)	CB-2A	9 09	36	2 SE	49	24 48	44	0 22
		CB-2B	10 28	37	1 ESE	56	24 44	29	1 32
		CB-2C	11 32	35	8 S	59	24 40	27	0 44
4/8/00	Burned Area (Plot 3)	CB-3A	14 06	34	7 E	70	24 30	15	0 60
		CB-3B	15 12	40	2 E	78	24 30	15	0 74
		CB-3C	16 11	37	5 NE/ENE	72	24 30	21	1 32
4/9/00	Unburned, grassy area	CB-4A	9 38	38	7 S	67	24 20	22	1 34
		CB-4B	10 40	33	5 2 S	71	24 18	20	1 88
		CB-4C	11 33	29	5 E	71	24 15	21	1 73
4/10/00	Unburned, grassy area	CB-5A	9 50	35	8 NNE/N	59	24 20	36	1 03
		CB-5B	10 55	32	10 NNE	60	24 20	36	1 62
		CB-5C	12 02	32	14 NE	60	24 20	37	2 64
4/11/00	Unburned, grassy area	CB-6A	8 18	32	3 ENE	43	24 40	70	0 89
		CB-6B	9 14	32	7 SE	48	24 40	61	0 64
		CB-6C	10 06	32	8 S	52	24 40	62	1 22
5/2/00	Burned Area (Plot 7)	CB-7A	9 30	30	6 SSE	62	24 36	48	0 90
		CB-7B	10 19	27	9 SE	64	24 30	40	1 22
		CB-7C	11 07	37	6 SE	67	24 30	39	1 19
5/2/00	Burned Area (Plot 8)	CB-8A	13 23	34	5 ESE	75	24 30	30	1 20
		CB 8B	14 19	35	2 WSW	75	24 25	29	1 20
		CB-8C[a]	15 14	34	5 NNE	79	24 25	27	1 52
5/3/00	Burned Area (Plot 9)	CB-9A	8 56	33	8 E	73	24 30	41	1 73
		CB-9B	9 46	27	NA	74	24 30	40	1 42
		CB-9C	10 59	28	9 NNW	74	24 30	39	1 57
6/21/00	Burned Area (Plot 10)	CB-10A[b]	8 21	43	5 NNE	67	24 40	34	3 00
		CB-10B	11 18	35	5 NE	70	24 60	30	3 00
		CB-10C	13 20	36	4 SE	78	24 90	21	3 00
6/21/00	Burned Area (Plot 11)	CB-11A	14 33	24	4 SE	75	24 80	20	3 32
		CB-11B	15 19	29	3 ENE	83	24 80	16	3 32
		CB-11C	16 13	24	3 SE	77	24 80	14	2 72
6/22/00	Burned Area (Plot 12)	CB-12A	7 56	30	3 ENE	76	24 60	30	3 00
		CB-12B	8 49	32	4 E	76	24 30	29	3 00
		CB-12C	9 45	30	3 E	79	24 60	23	2 72
6/22/00	Unburned, grassy area	CB-13A	13 26	29	5 E	88	24 40	11	3 49
		CB-13B	14 13	29	3 E	88	24 40	11	2 86
		CB-13C	15 02	32	5 ENE	86	24 40	11	3 16
6/23/00	Unburned, grassy area	CB-14A	7 30	33	3 SE/S	68	24 20	38	4 06
		CB-14B	8 27	26	6 S	68	24 20	40	2 12
		CB-14C	9 16	29	5 S	70	24 20	40	3 32
6/23/00	Unburned, grassy area	CB-15A	10 22	31	3 S	79	24 30	10	3 49
		CB-15B	11 16	29	3 S	82	24 30	15	NA
		CB-15C	12 05	29	3 S	92	24 35	8	3 16

[a]Run CB-8C started at 15 14 suspended at 15 18 restarted at 15 23 and ended at 15 53
[b]Run CB-10A started at 8 21, suspended at 8 30 restarted at 10 21 and ended at 10 55
NA = No data available

The average PM concentrations from the wind tunnel tests are presented in Table 2 As expected, the average PM-10 concentration in the wind tunnel effluent is much higher for the burned areas (CB-1 to CB-3, CB-7 to CB-12) than for the unburned areas (CB-4 to CB-6, CB-13 to CB-15) Even though high ambient winds were encountered between the time of the prescribed burn (April 6) and the beginning of the first test series (April 7), the average PM-10 erosion potential was found to range from 6 3 to 8 7 times the average PM-10 erosion potential for unburned grassland adjacent to the burned area

The PM-10 concentrations observed for the June wind tunnel tests of the burned area (CB-10, 11, 12) are slightly higher than the concentrations for the May tests due to the soil moisture level Soil moisture readings taken in the field during the May test series indicated a damp surface while the April and June readings indicated the soil to be dry Also, the June wind tunnel tests of the unburned grassland show low additional PM-10 emissions, consistent with results from the April tests of unburned grassland

It should also be noted that the actual average PM-10 concentration calculated from the tunnel effluent sampler was several times higher than the average PM-10 concentration indicated by the DustTRAK This reflects the fact that while the coarse mode of the PM-10 (particles larger than 2 5 µm) constitutes much of the PM-10 sample mass, it does not scatter light very effectively This behavior also tends to inflate the PM-2 5/PM-10 ratio given in the last column of Table 2

The logging mode of the DustTRAK provided 6-sec average concentration values for each of the test runs After subtracting out the minimum concentration recorded by the DustTRAK, which was assumed to be background, these values were used to find an average concentration value from the beginning of the test run to the end of a selected 10-m wind speed The average concentration along with the tunnel volumetric flow rate, the length of time from the beginning of the test until the end of testing at the specified wind speed, and the exposed test surface area were used to determine the erosion potential for that wind speed In order to account for the reduced capability of the DustTRAK to detect the coarse PM-10 mode, the erosion potential values estimated from the time-integrated DustTRAK PM-10 concentration for each wind speed were multiplied by the ratio of the effluent sampler average PM-10 concentration to the DustTRAK average PM-10 concentration

Table 3 presents calculated values of PM-10 and TP erosion potential for each test run Average erosion potential values for the three test periods are given in Table 4 Although the same incremental pressure drops for the wind tunnel centerline wind speed were used for the three test periods, changes in the roughness height of the surface over the three-month period resulted in increases in the equivalent 10-m wind speeds Higher maximum wind speeds than shown in Table 4 were reached in some runs during the June test period, but they were not consistent enough to provide for a representative average value

Table 2. Wind Tunnel Test Results: Average Concentrations

Date	Run no	Duration (min)	Average effluent PM-10 conc (mg/m^3)	Background PM-10 conc (mg/m^3)	Net[a] PM-10 conc (mg/m^3)	TP conc (mg/m^3)	Average DustTRAK PM-10 conc (mg/m^3)	Ratio of effluent/ DustTRAK PM-10 conc	Average DustTRAK PM-2 5 conc (mg/m^3)	Ratio of DustTRAK PM-2 5 conc / PM-10 conc
4/7/00	CB-1	126	0 262	0 079	0 183	0 458	0 038	6 89	0 022	0 58
4/8/00	CB-2	108	0 119	0 057	0 063	0 258	0 017	7 14	0 016	0 97
4/8/00	CB-3	111	0 153	0 057	0 097	0 257	0 022	6 97	0 018	0 81
4/9/00	CB-4	100	0 061	0 010	0 051	0 122	0 010	5 90	0 005	0 48
4/10/00	CB-5	99	0 027	0 021	0 006	0 068	0 010	2 63	0 005	0 45
4/11/00	CB-6	96	0 029	0 023	0 006	0 092	0 023	1 27	0 021	0 92
5/2/00	CB-7	94	0 086	0 040	0 046	0 447	0 028	3 11	0 019	0 69
5/2/00	CB-8	103	0 132	0 040	0 092	0 908	0 028	4 65	0 013	0 46
5/3/00	CB-9	88	0 084	0 028	0 056	0 337	0 021	3 96	0 011	0 54
6/21/00	CB-10	114	0 241	0 029	0 211	3 504	0 034	7 15	0 010	0 31
6/21/00	CB-11	77	0 134	0 029	0 105	0 806	0 013	10 06	0 012	0 92
6/22/00	CB-12	92	0 118	0 029	0 089	1 447	0 019	6 13	0 010	0 52
6/22/00	CB-13	90	0 047	0 028	0 018	0 091	0 010	4 84	0 007	0 67
6/23/00	CB-14	88	0 031	0 039	<0 001	0 221	0 009	3 61	0 006	0 65
6/23/00	CB-15	89	0 036	0 039	<0 001	0 371	0 010	3 64	0 006	0 57

[a] Net = Average effluent concentration—Background concentration

Table 3. Wind Tunnel Test Results. Erosion Potentials

Date	Run no	Average roughness height, Z_0 (cm)	Maximum wind speed (mph) at tunnel CL[a]	Equivalent maximum wind speed (mph) at 10-m height[b]	Corresponding friction velocity[b] (cm/s)	Erosion potential/loss[c] (g/m^2)		
						TP	PM-10	Loss ratio (PM-10/TP)
4/7/00	CB-1	0 85	40 3	97 6	244 7	1 33	0 65	0 483
4/8/00	CB-2	0 66	40 3	97 6	244 7	0 61	0 19	0 311
4/8/00	CB-3	0 89	40 3	97 6	244 7	0 62	0 30	0 483
4/9/00	CB-4	1 65	39 7	110 1	301 0	0 31	0 14	0 454
4/10/00	CB-5	1 76	40 3	111 9	305 8	0 13	0 02	0 127
4/11/00	CB-6	0 92	40 3	111 9	305 8	0 18	0 02	0 087
5/2/00	CB-7	1 10	37 0	100 5	271 4	1 07	0 12	0 113
5/2/00	CB-8	1 31	40 3	109 6	295 8	2 50	0 26	0 106
5/3/00	CB-9	1 57	37 2	101 2	273 3	0 76	0 14	0 182
6/21/00	CB-10	3 00	38 6	138 3	425 9	11 09	0 67	0 061
6/21/00	CB-11	3 12	29 2	104 7	322 4	1 67	0 23	0 135
6/22/00	CB-12	2 91	35 8	128 4	395 3	3 65	0 23	0 063
6/22/00	CB-13	3 17	39 3	145 2	452 5	0 16	0 05	0 295
6/23/00	CB-14	3 16	34 8	128 6	400 6	0 45	–0 02	–0 041
6/23/00	CB-15	3 32	37 5	138 8	432 4	0 83	–0 01	–0 007

[a] Average maximum wind speed at tunnel centerline (CL) for all three tests

[b] Average roughness height over three runs used to calculate equivalent 10-m wind speed and friction velocity

[c] Calculated using net mass and the alternative method referred to on page 8 and described in more detail in Appendix D

Table 4. DustTRAK Average PM-10 Erosion Potentials

April 2000				May 2000		June 2000			
Burned		Unburned		Burned		Burned		Unburned	
Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)
12	0 000	14	0 000	14	0 000	18	0 000	19	0 000
24	0 001	28	0 000	28	0 001	36	0 001	38	0 000
36	0 002	42	0 001	41	0 002	54	0 002	56	0 001
48	0 007	56	0 003	55	0 005	72	0 006	75	0 002
61	0 011	70	0 004	69	0 009	90	0 012	94	0 003
73	0 018	83	0 006	83	0 014	109	0 020	113	0 005
85	0 029	97	0 009	96	0 022	127	0 042	132	0 007
97	0 057	111	0 013	110	0 033				

Figure 6 shows the average erosion potential value versus wind speed (mph) at a 10-m height after adjustment of the DustTRAK PM-10 concentrations The exponential rate of increase of the erosion potential with wind speed can be seen It is evident that above 40 mph, there is a higher rate of increase of PM-10 erosion potential with 10-m wind speed

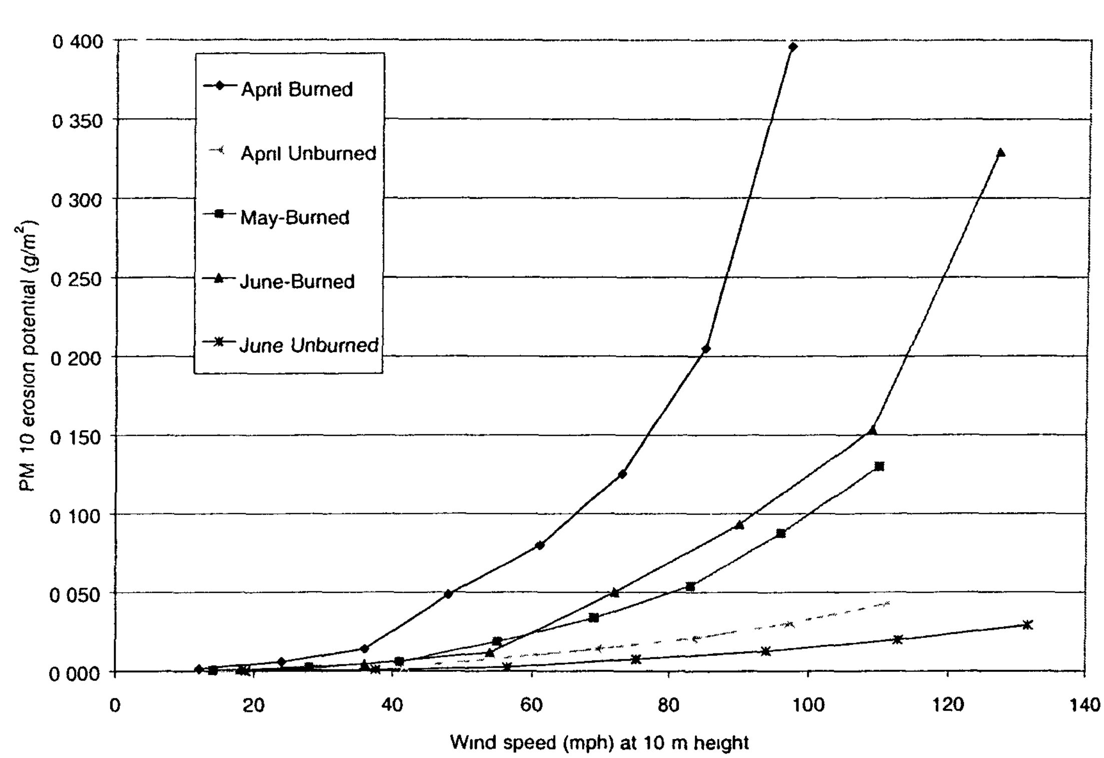

Figure 6 PM-10 Erosion Potential vs 10-m Wind Speeds As Determined From DustTRAK Data (Erosion potential values adjusted based on ratio of effluent concentration/DustTRAK concentration)

Based on the data available, a linear interpretation was made between consecutive data points (above and below the desired wind speed value) to determine a DustTRAK erosion potential value at a 95-mph wind speed and also for the maximum wind speed during each test run The ratio of these two values was then used to adjust the erosion potential (see Table 3) to a 95-mph wind speed at a 10-m height The 95-mph PM-10 erosion potentials for all the test runs are presented in Table 5 The resulting erosion potential history can be seen in Figure 7

From Figure 7, the PM-10 erosion potential of the burned area appears to decay in time with the regrowth of vegetation, although the average erosion potential for the May tests is similar to that found for the June tests The average erosion potential for the May test would have been higher except for the effect of higher soil moisture in May as compared to the other test periods The PM-10 erosion potential for the unburned grassland remains consistently low, in the range of 0 05 g/m^2, as seen from April tests CB-4, 5, 6 and June tests CB-13, 14, 15

Table 5. PM-10 Erosion Potentials at 95-mph

Date	Run no	PM-10 erosion potential (g/m²)
4/7/00	CB-1	0 59
4/8/00	CB-2	0 17
4/8/00	CB-3	0 28
4/9/00	CB-4	0 10
4/10/00	CB-5	0 01
4/11/00	CB-6	0 01
5/2/00	CB-7	0 10
5/2/00	CB-8	0 18
5/3/00	CB-9	0 12
6/21/00	CB-10	0 17
6/21/00	CB-11	0 18
6/22/00	CB-12	0 07
6/22/00	CB-13	0 02
6/23/00	CB-14	< 0 02
6/23/00	CB-15	< 0 02

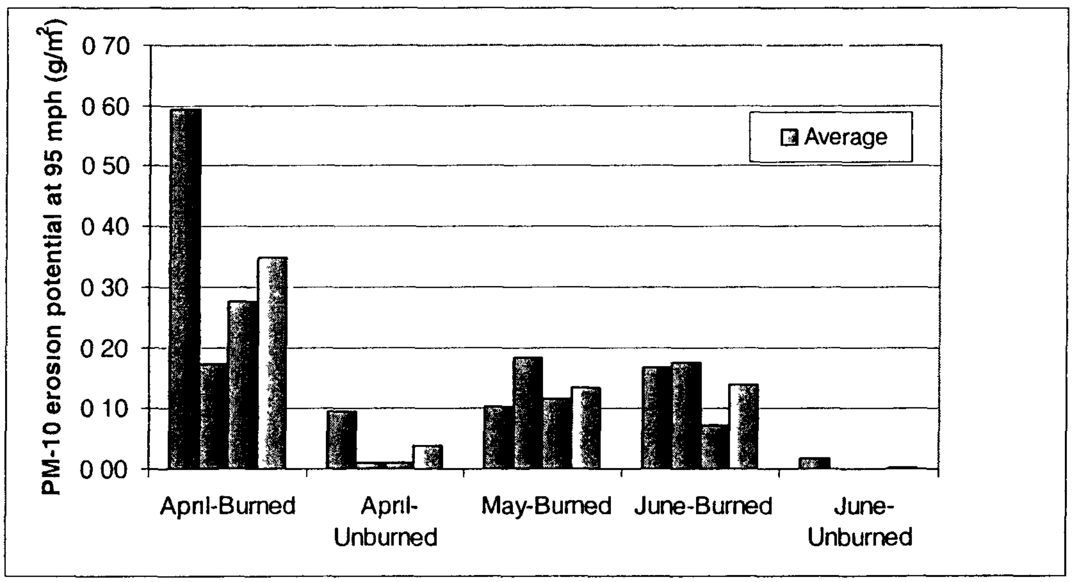

Figure 7. Erosion Potential History at 95-mph Wind Speed

Section 4.
Results of Laboratory Tests

Laboratory tests of surface soil samples were performed (a) to characterize the soil emission potential as a function of moisture content, and (b) to determine the PM-10 emission components (organic and elemental carbon)

4.1 Dustiness Testing

Dustiness testing was performed on samples of surface soil to characterize the potential for release of airborne PM, specifically the PM-10 and PM-2 5 components, when the dry soil is disturbed Dustiness tests were also run under varying soil moisture levels to provide information on the mitigative effect of soil moisture in reducing PM-10 and PM-2 5 emissions

4 1.1 Sample Preparation

The six surface soil samples collected from the Rocky Flats prescribed burn area were analyzed for moisture content prior to dustiness testing The samples were considered to be representative of the controlled burn area Because the samples were collected on different dates and times, they represented different moisture levels, as shown in Table 6 Except for the samples collected on April 10, 2000, the moisture levels indicated that the surface soil was relatively dry

Table 6. Moisture Levels of "Burned Area" Surface Soil Samples

Sample label	Location of sample collection	Date collected	Current moisture (%)
4/7 Surface Soil "D"	Adjacent to test plot CB-1A	4/7/00	1 4
4/8 Adjacent to CB-2	Adjacent to test plot CB-3B	4/8/00	2 3
4/10 Burned Area #3	Southwest corner of burned area	4/10/00	7 6
4/10 Burned Area #4	Southwest corner of burned area	4/10/00	17 5
5/3 Burned Area #1	Adjacent to test plots CB-7,8,9	5/3/00	1 8
5/3 Burned Area #2	Adjacent to test plots CB-7,8,9	5/3/00	1 4

When the individual soil samples with low moisture contents (in the range of 1 4% to 2 3%) were tested for PM-10 dustiness, the results given in Table 7 were obtained These initial tests also showed variations in the dustiness index (by a factor of 3) within only a 1 percent range of moisture content This may have reflected differences in soil texture resulting from differences in compaction As a result, it was decided that the samples should be composited to provide better representation of surface soil conditions in the prescnbed burn area, for purposes of developing a relationship between soil dustiness and moisture content

Table 7. Results of Preliminary PM-10 Dustiness Tests

Test ID	Sample label	Moisture (%)	Mass poured (g)	Mass collected (mg)	Dustiness index (mg/kg)
1	5/3 Burned Area #2	1 4	635 0	3 075	4 8
2	5/3 Burned Area #1	1 8	526 0	4 723	9 0
3	4/7 Surface Soil "D"	1 4	490 3	4 293	8 8
4	4/8 Adjacent to Plot CB-2	2 3	489 5	8 157	16 7

The procedure for compositing the soil samples was to (a) pass each sample through a 1-cm sieve in order to eliminate large rocks and sticks that might be present, as is standard procedure for dustiness testing, (b) dry each sample in a 110°C oven overnight, and (c) combine all six samples (in equal amounts) into one composite sample and seal in an air tight container until ready to be used The composite sample was then split into as many subsamples as needed for testing and the subsamples were moistunzed to the percentages desired for testing

The moisture levels selected for dustiness testing were 0%, 2%, 4%, 6%, and 8% The following procedure was used for moistunzing subsamples that had been oven dned

1 Tare weigh a clean pan
2 Record the weight of the pan and dry sample
3 Determine the weight of the sample
4 Calculate the amount of water (g) to be added to the sample, using the sample weight and the desired moisture content

   Example Desired moisture content = 4 0%
   Pan tare weight = 18 6 g Pan + Sample = 518 6 g Sample = 500 0 g
   Moisture to be added $\frac{500\ 0\ g}{(100\%-4\%)} = \frac{x\ g}{4\%}$ x = 20 8 g

5 Spray the sample, weighing it on a balance, until the desired weight is observed
6 Return sample to sealed container for at least 6 hrs to ensure that moisture is evenly distributed

The scope of work required dustiness charactenzation of the soil samples for both PM-10 and PM-2 5 The dustiness tests for PM-10 were run first, and then the samples were poured a second time for PM-2 5 dustiness charactenzation A total of ten tests were performed, not including blank runs that were used to account for the effects of filter handling A total of three filters were used for blank runs dunng the testing penod The order of testing is listed below in Table 8

Table 8. Dustiness Test Matrix

Moisture level	PM-10 Dustiness test	PM-2 5 Dustiness test
0%	1	6
2%	2	7
4%	3	8
6%	4	9
8%	5	10

4 1 2 Results of Dustiness Testing

The results of the PM-10 and PM-2 5 dustiness tests are given in Table 9 The PM-10 dustiness was found to decrease with soil moisture content above 2 percent, as expected This result is illustrated in Figure 8 However, for bone dry soil, the PM-10 dustiness is lower than at 2 percent moisture This likely reflects the tendency of soil particles to bond because of electrostatic charging at very low moisture levels

The PM-2 5 dustiness appears to be relatively independent of moisture content There is an apparent anomaly at the 8 percent moisture level because the PM-2 5 dustiness index exceeds the PM-10 dustiness index This may reflect the drying of the sample during the three pours that were necessary to quantify the dustiness of this sample

Table 9. PM-10 and PM-2.5 Dustiness Test Results

Approximate Moisture (%)	Test ID	Mass poured (g)	PM-10 Mass collected (mg)	PM-10 Dustiness index (mg/kg)	Test ID	Mass poured (g)	PM-2 5 Mass collected (mg)	PM-2 5 Dustiness index (mg/kg)
0	6	428 4	2 296	5 4	11	646 7	1 519	2 3
2	7	293 0	7 012	29 3	12	503 1	0 841	1 7
4	8	211 9	5 182	24 5	13	465 2	3 288	7 1
6	9	213 8	2 551	11 9	14	444 6	1 624	3 7
8	10	622 3	0 485	0 8	17	647 7	3 014	4 7

Test 15—unusable due to filter edge tearing
Test 16 and 18—blank test runs

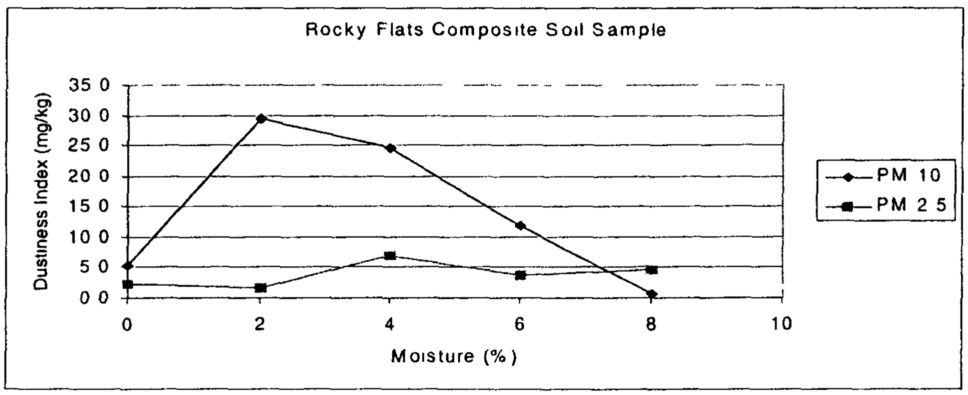

Figure 8. Soil Dustiness Index vs. Soil Moisture Content

4.2 Carbon Analysis

Table 10 presents the carbon analysis results of the PM-10 filters from each test run All analysis results were corrected for EC and OC present on blank filters that were not exposed to airflow The EC and OC masses on the blank-corrected background filters were also adjusted to the same run time as used for the filters exposed to wind tunnel emissions

Table 11 gives the abundance of EC and OC in the PM-10 that was generated by wind erosion of each test surface (after subtraction of the background contribution) The EC and OC abundance in PM-10 emissions for each test run are shown graphically in Figure 10

Several observations can be made from examination of Figure 9 First, both EC and OC are present to a much greater extent in PM-10 emissions from the burned area as compared to PM-10 emissions from adjacent unburned grassland Second, EC in the emissions from the burned area tends to decrease as vegetation is reestablished, but OC does not The higher emissions from the June tests of the burned area (CB-10 through CB-12) reflect the much drier conditions than had occurred in earlier testing The negative values shown in Figure 10 for five of the six tests on the unburned, grassy area indicate inadequate treatment for blanks

Clearly, OC dominates the carbon constituent of PM-10 for background samples and unburned area emissions In contrast, the EC emissions from soil erosion of the prescribed burn area represent a much larger fraction of the total PM-10 emissions Moreover, the EC emissions decrease from April to May to June (i e , 770 µg/filter in April, 270 µg/filter in May, and 136 µg/filter in June)

Table 10 Carbon Analysis Results

Run	Emission sampler: PM-10 mass collected on filter (mg)	Sampler run time (min)	Blank corrected[a] organic carbon (μg/filter)	Blank corrected[a] elemental carbon (μg/filter)	Background sampler: PM-10 mass collected on filter[c] (mg)	Sampler run time (min)	Adjusted net mass[b] (mg)	Adjusted[b] blank corrected[a] organic carbon[c] (μg/filter)	Adjusted[b] blank corrected[a] elemental carbon[c] (μg/filter)
CB-1	36 85	126	3042 6	2328 4	12 55	141	11 21	879 19	329 76
CB-2	14 05	108	2254 8	1599 2	15 72	249	6 82	1079 94	406 94
CB-3	18 75	111	2765 1	1547 1	15 72	249	7 01	1109 94	418 24
CB-4	6 35	100	996 6	–38 9	0 92	104	0 89	91 79	–28 59
CB-5	2 50	99	389 7	–26 3	2 15	101	2 11	259 27	25 40
CB-6	2 65	96	28 7	–10 3	2 70	112	2 31	203 24	48 31
CB-7	9 15	94	1912 9	769 5	9 80	217	4 25	737 97	88 55
CB-8	15 35	103	3261 1	1076 8	9 80	217	4 65	808 63	97 03
CB-9	8 40	88	956 4	784 0	2 97	93	2 82	345 95	220 01
CB-10	33 70	114	5978 7	802 6	7 90	199	4 53	603 86	115 35
CB-11	14 30	77	1717 7	689 5	7 90	199	3 06	407 87	77 92
CB-12	14 95	92	2337 9	267 0	4 58	98	4 29	378 81	10 43
CB-13	7 40	90	2004 2	50 8	4 52	100	4 07	828 50	86 55
CB-14	5 75	88	593 7	216 2	5 58	97	5 06	630 71	162 18
CB-15	6 30	89	1542 7	430 7	5 58	97	5 12	637 87	164 02

[a] Blank corrected values based on average of all field and lab blanks
[b] Background values time-weighted to reflect mass seen during emission sampler run time
[c] Mass collected on background filter assumed to be half PM-10

Table 11. Carbon Contribution to PM-10 Mass from Wind Erosion Test

Run	Net values								
	PM-10 mass (mg)	Organic carbon (µg/ filter)	Organic carbon (mg)	%	Elemental carbon (µg/ filter)	Elemental carbon (mg)	%	Total carbon (mg)	%
CB-1	25 64	2163 43	2 16	8 44	1998 67	2 00	7 80	4 16	16 2
CB-2	7 23	1174 88	1 17	16 25	1192 29	1 19	16 49	2 37	32 7
CB-3	11 74	1655 18	1 66	14 10	1128 89	1 13	9 62	2 78	23 7
CB-4	5 46	904 83	0 90	16 57	–10 28	–0 01	–0 19	0 89	16 4
CB-5	0 39	130 45	0 13	33 23	-51 67	–0 05	–13 16	0 08	20 1
CB-6	0 34	–174 52	–0 17	–51 98	–58 58	–0 06	–17 45	–0 23	–69 4
ssssCB-7	4 90	1174 95	1 17	23 95	680 98	0 68	13 88	1 86	37 8
CB-8	10 70	2452 49	2 45	22 92	979 80	0 98	9 16	3 43	32 1
CB-9	5 58	610 47	0 61	10 93	564 02	0 56	10 10	1 17	21 0
CB-10	29 17	5374 86	5 37	18 42	687 28	0 69	2 36	6 06	20 8
CB-11	11 24	1309 85	1 31	11 65	611 61	0 61	5 44	1 92	17 1
CB-12	10 66	1959 11	1 96	18 39	256 60	0 26	2 41	2 22	20 8
CB-13	3 33	1175 72	1 18	35 33	–35 72	–0 04	–1 07	1 14	34 3
CB-14	0 69	–36 99	–0 04	–5 34	54 05	0 05	7 81	0 02	2 5
CB-15	1 18	904 85	0 90	76 37	266 71	0 27	22 51	1 17	98 9

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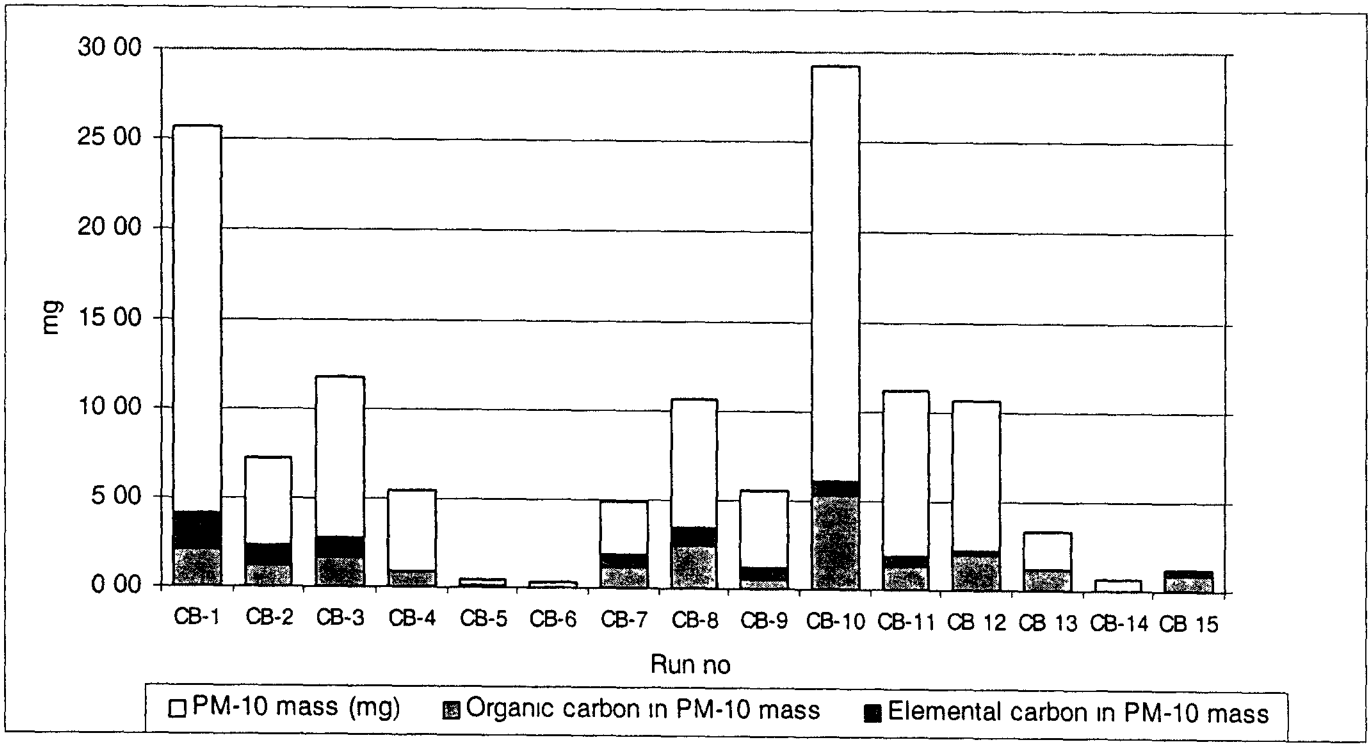

Figure 9. Abundance of EC and OC in PM-10 from Erosion Surface

Section 5. Conclusions

During the three months of testing, wind erosion particulate emissions from the prescribed burn area at Rocky Flats were found to be much less than has been previously observed by MRI on disturbed land at other test locations in the area The burned grassland was observed to retain many of the characteristics that limit wind erosion—including soil crusts, rocks that protect the surface soil, and grass clumps that will revegetate

PM-10 erosion potentials from the prescribed burn areas were always somewhat greater than for unburned areas, even for the June tests—approximately 2½ months after the burn Although the differences were reduced as vegetation was re-established, they were still evident This was clearly due to the protection afforded by the dead grass thatch that completely covered the unburned areas, but had been destroyed by the fire on the burned areas Even though the burned areas had revegetated to a large extent with tall, thin plants by the June test period, bare soil that constituted an emission source that was still visible between the revegetating plants

During the May tests, the mitigative effects of soil moisture were evident at moderate temperatures This was confirmed by laboratory dustiness tests However, because the soil surface dries quickly in the relatively low humidity environment of Rocky Flats, especially at warm temperatures, the mitigative effect of rainfall is usually transient

Although the results of the wind erosion tests on the Rocky Flats prescribed burn area did not show a clearly evident threshold velocity for the onset of wind erosion, PM-10 erosion potentials above 40 mph (at a height of 10 m) were observed to increase at a higher rate with increasing wind speed Emission spikes occurred as the wind speed was raised in 5-mph increments at the tunnel centerline Spikes for lower velocity winds were smaller and quickly decayed in time as the wind speed was held to a constant value for a period of 2 to 8 min As the wind speed increased to higher plateaus, the spikes were larger and decayed at a slower rate These observed phenomena indicate the contribution of multiple release mechanisms to the overall wind erosion dynamics

Appendix A

Results of Gravimetric Analysis

Table A-3. Blank Filter weights (mg)

Date	Run No	Filter No	Tare weight	Final weight	Net weight
4/7/00	CB-1	0012003	3614 25	3613 75	–0 50
4/7/00	CB-1	0012004	3611 15	3610 95	–0 20
4/8/00	CB-2,3	0012009	3580 95	3579 90	–1 05
4/8/00	CB-2,3	0012010	3579 60	3578 95	–0 65
4/9/00	CB-4	0012014	3578 20	3577 45	–0 75
4/9/00	CB-4	0012015	3556 35	3556 30	–0 05
4/10/00	CB-5	0012018	3599 55	3598 80	–0 75
4/10/00	CB-5	0012019	3601 15	3601 05	–0 10
4/11/00	CB-6	0012022	3601 65	3601 10	–0 55
4/11/00	CB-6	0012023	3570 75	3570 00	–0 75
4/11/00	CB-6	0012025	3588 95	3588 40	–0 55
5/2/00	CB-7,8	0012030	3304 60	3304 50	–0 10
5/2/00	CB-7,8	0012031	3284 35	3284 20	–0 15
5/3/00	CB-9	0012034	3301 05	3301 30	0 25
6/21/00	CB-10,11	0012045	3509 00	3511 65	2 65
6/21/00	CB-10,11	0012046	3519 10	3522 50	3 40
6/22/00	CB-12,13	0012050	3517 60	3520 25	2 65
6/22/00	CB-12,13	0012052	3302 90	3305 70	2 80
6/23/00	CB-14,15	0012058	3338 70	3341 60	2 90
6/23/00	CB-14,15	0012059	3320 10	3322 75	2 65
6/23/00	CB-14,15	0012060	3324 85	3327 30	2 45
6/23/00	CB-14,15	0012061	3298 75	3301 00	2 25
6/23/00	CB-14,15	0012062	3260 65	3262 60	1 95

April average blank filter weight = –0 54 mg
May average blank filter weight = 0 00 mg
June average blank filter weight = 2 63 mg

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Table A-4. Dustiness Test Filter weights (mg)

Test ID	Filter no	Tare weight	Final weight	Net mass collected	Blank corrected net weight
1	0017001	145 040	148 137	3 097	3 075
2	0017002	144 962	149 707	4 745	4 723
3	0017003	145 868	150 183	4 315	4 293
4	0017004	145 430	153 609	8 179	8 157
5	0017005	146 360	146 382	0 022	
6	0017006	144 423	146 806	2 383	2 296
7	0017007	145 000	152 099	7 099	7 012
8	0017008	143 781	149 050	5 269	5 182
9	0017009	145 180	147 818	2 638	2 551
10	0017010	145 027	145 599	0 572	0 485
11	0017011	145 122	146 728	1 606	1 519
12	0017012	145 262	146 190	0 928	0 841
13	0017013	144 439	147 814	3 375	3 288
14	0017014	143 437	145 148	1 711	1 624
15	0017015	144 367	144 829	0 462	0 375
16	0017016	144 555	144 608	0 053	
17	0017017	144 395	147 496	3 101	3 014
18	0017018	144 297	144 418	0 121	

Appendix B

Carbon Analysis Data

Table B-1. Carbon Analysis Data
Desert Research Institute Results

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPAREA
12001	0012001	CB-1/Background	4/7/00		3065 80	219 50	797 50	59 50	3863 30	276 00	406 0
12002	0012002	CB 1/Test	4/7/00	m2	4140 70	278 90	2387 90	162 80	6528 50	433 80	406 0
12003	0012003	CB 1/Field Blank	4/7/00		1018 90	127 60	12 80	26 90	1031 80	141 90	406 0
12004	0012004	CB-2/Field Blank	4/7/00		859 50	123 00	0 00	25 70	859 50	137 20	406 0
12005	0012005	CB 2&3/Background	4/8/00	m2	6077 80	391 60	1935 90	132 90	8013 70	524 90	406 0
12006	0012006	CB-2/Test	4/8/00		3352 90	235 00	1658 70	114 60	5011 60	342 60	406 0
12007	0012007	CB 3/Test	4/8/00		3863 20	263 20	1606 60	111 20	5469 80	369 90	406 0
12009	0012009	CB-3/Field Blank	4/8/00		694 70	119 00	0 00	25 70	694 70	133 40	406 0
12010	0012010	CB-3/Field Blank	4/8/00		782 20	121 00	0 00	25 70	782 20	135 30	406 0
12011	0012011	CB 4/Background	4/9/00		1289 00	136 60	0 00	25 70	1289 00	150 20	406 0
12012	0012012	Carbon Analysis Blank	Apr Test Period		927 80	124 90	1 40	25 70	929 20	139 00	406 0
12013	0012013	CB-4/Test	4/9/00		2094 70	170 50	20 60	28 70	2115 30	184 20	406 0
12014	0012014	CB 4/Field Blank	4/9/00		860 80	123 10	37 50	34 70	898 30	138 20	406 0
12015	0012015	CB-4/Field Blank	4/9/00		1091 20	129 80	92 30	62 90	1183 40	146 60	406 0
12016	0012016	CB-5/Background	4/10/00		1627 10	149 70	111 30	73 90	1738 50	167 50	406 0
12017	0012017	CB-5/Test	4/10/00		1487 80	144 10	33 20	33 00	1521 00	158 70	406 0
12018	0012018	CB 5/Field Blank	4/10/00		802 60	121 50	19 60	28 50	822 20	136 30	406 0
12019	0012019	CB 5/Field Blank	4/10/00		1030 80	127 90	47 80	39 30	1078 60	143 30	406 0
12020	0012020	CB-6/Background	4/11/00		1572 30	147 50	172 20	110 20	1744 50	167 80	406 0
12021	0012021	CB 6/Test	4/11/00		1126 80	131 00	49 20	40 00	1176 00	146 40	406 0
12022	0012022	CB 6/Field Blank	4/11/00		723 40	119 60	0 00	25 70	723 40	134 00	406 0
12023	0012023	CB 6/Field Blank	4/11/00		1031 40	128 00	20 70	28 80	1052 10	142 50	406 0
12024	0012024	Carbon Analysis Blank	Apr Test Period		1057 90	128 80	13 00	27 00	1070 90	143 10	406 0
12025	0012025	CB 6/Field Blank	4/11/00		1275 80	136 10	32 80	32 80	1308 60	150 90	406 0
12027	0012027	CB 7&8/Background	5/2/00		4505 30	299 70	468 30	40 70	4973 60	340 40	406 0
12028	0012028	CB 7/Test	5/2/00		3011 00	216 60	829 00	61 50	3840 00	274 70	406 0
12029	0012029	CB 8/Test	5/2/00		4359 20	291 30	1136 30	80 70	5495 50	371 40	406 0
12030	0012030	CB 7&8/Field Blank	5/2/00		750 60	120 30	5 20	25 90	755 80	134 70	406 0
12031	0012031	CB 7&8/Field Blank	5/2/00		696 50	119 00	0 00	25 70	696 50	133 40	406 0
12032	0012032	CB 9/Background	5/3/00		1829 30	158 40	524 50	43 70	2353 80	195 50	406 0
12033	0012033	CB 9/Test	5/3/00		2054 50	168 60	843 50	62 30	2898 00	223 10	406 0

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Table B-1 Carbon Analysis Data Desert Research Institute Results (Continued)

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPAREA
12034	0012034	CB 9/Field Blank	5/3/00		837 90	122 50	114 50	75 80	952 40	139 70	406 0
12035	0012035	Carbon Analysis Blank	May Test Period		739 40	120 00	38 20	35 00	777 60	135 20	406 0
12037	0012037	Carbon Analysis Blank	May Test Period		963 70	125 90	204 10	129 60	1167 70	146 10	406 0
12040	0012040	Carbon Analysis Blank	May Test Period		2231 20	177 00	334 10	34 20	2565 30	206 00	406 0
12042	0012042	CB 10/Test	6/21/00	m2	7076 80	451 10	862 10	63 50	7938 90	520 20	406 0
12043	0012043	CB-10&11/Background	6/21/00		3206 30	227 10	462 20	40 40	3668 50	265 00	406 0
12044	0012044	CB 11/Test	6/21/00		2815 80	206 40	749 00	56 60	3564 80	259 30	406 0
12046	0012046	CB 10&11/Field Blank	6/21/00		1430 90	141 90	0 00	25 70	1430 90	155 30	406 0
12047	0012047	Carbon Analysis Blank	Jun Test Period		2275 70	179 10	332 60	34 10	2608 40	208 20	406 0
12048	0012048	CB-12/Background	6/22/00		1905 10	161 80	81 70	57 00	1986 90	178 30	406 0
12049	0012049	CB 12/Test	6/22/00		3436 00	239 50	326 50	204 80	3762 50	270 30	406 0
12050	0012050	CB-12/Field Blank	6/22/00		1237 60	134 80	166 40	106 70	1403 90	154 30	406 0
12051	0012051	Carbon Analysis Blank	Jun Test Period		1139 10	131 40	125 50	82 20	1264 60	149 40	406 0
12052	0012052	CB-12&13/Field Blank	6/22/00		1325 60	137 90	31 60	32 40	1357 20	152 60	406 0
12053	0012053	CB 13/Background	6/22/00		2939 20	212 80	251 80	158 80	3191 00	238 80	406 0
12054	0012054	CB 13/Test	6/22/00		3102 30	221 50	110 30	73 30	3212 60	239 90	406 0
12055	0012055	CB 14&15/Background	6/23/00		2488 50	189 60	417 00	38 10	2905 50	223 50	406 0
12056	0012056	CB 14/Test	6/23/00		1691 80	152 40	275 70	173 50	1967 50	177 50	406 0
12057	0012057	CB 15/Test	6/23/00		2640 80	197 30	490 20	41 80	3131 00	235 50	406 0
12058	0012058	CB 14&15/Field Blank	6/23/00		1098 30	130 10	0 00	25 70	1098 30	143 90	406 0
12059	0012059	CB 14&15/Field Blank	6/23/00		1461 70	143 10	0 00	25 70	1461 70	156 50	406 0
12060	0012060	CB 14&15/Field Blank	6/23/00		807 20	121 70	0 00	25 70	807 20	135 90	406 0
12061	0012061	CB-14&15/Field Blank	6/23/00		909 50	124 40	4 80	25 90	914 30	138 60	406 0
12062	0012062	CB-14&15/Field Blank	6/23/00		1224 10	134 30	171 80	110 00	1395 90	154 00	406 0
12063	0012063	Carbon Analysis Blank	Jun Test Period		651 10	118 00	0 00	25 70	651 10	132 50	406 0
12074	0012074	Carbon Analysis Blank	Extra		1058 70	128 80	0 00	25 70	1058 70	142 70	406 0
12075	0012075	Carbon Analysis Blank	Extra		1063 70	129 00	15 50	27 50	1079 30	143 40	406 0
12076	0012076	Carbon Analysis Blank	Extra		2177 20	174 40	140 20	91 00	2317 50	193 80	406 0

m2 Non white carbon punch after carbon analysis, indicative of mineral particles in deposit
QID Filter ID
OETF TOR analysis flag (see CHEMFLAG doc)
OCTC Organic carbon concentration (µg/filter)
OCTU Organic carbon concentration uncertainty (µg/filter)
ECTC Elemental carbon concentration (µg/filter)
ECTU Elemental carbon concentration uncertainty (µg/filter)
TCTC Total carbon concentration (µg/filter)
TCTU Total carbon concentration uncertainty (µg/filter)
DEPAREA Filter deposit area (406 cm^2)

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CHEMFLAG DOC

Table
Chemical Analysis Data Validation Flags[a]

Validation Flag	Sub Flag	Description
b		Blank
	b1	Field/dynamic blank
	b2	Laboratory blank
	b3	Distilled-deionized water blank
	b4	Method blank
	b5	Extract/solution blank
	b6	Transport blank
c		Analysis result reprocessed or recalculated
	c1	XRF spectrum reprocessed using manually adjusted background
d		Sample dropped
f		Filter damaged or ripped
	f1	Filter damaged, outside of analysis area
	f2	Filter damaged, within analysis area
	f3	Filter wrinkled
	f4	Filter stuck to PetriSlide
	f5	Teflon membrane separated from support ring
	f6	Pinholes in filter
g		Filter deposit damaged
	g1	Deposit scratched or scraped, causing a thin line in the deposit
	g2	Deposit smudged, causing a large area of deposit to be displaced
	g3	Filter deposit side down in PetriSlide
	g4	Part of deposit appears to have fallen off, particles on inside of PetriSlide
	g5	Ungloved finger touched filter
	g6	Gloved finger touched filter
h		Filter holder assembly problem
	h1	Deposit not centered
	h2	Sampled on wrong side of filter
	h4	Filter support grid upside down- deposit has widely spaced stripes or grid pattern
	h5	Two filters in PetriSlide—analyzed separately
i		Inhomogeneous sample deposit
	i1	Evidence of impaction—deposit heavier in center of filter
	i2	Random areas of darker or lighter deposit on filter
	i3	Light colored deposit with dark specks
	i4	Non-uniform deposit near edge—possible air leak

Table
Chemical Analysis Data Validation Flags[a] (Continued)

Validation Flag	Sub Flag	Description
m		Analysis results affected by matrix effect
	m1	Organic/elemental carbon split undetermined due to an apparent color change of non-carbon particles during analysis, all measured carbon reported as organic
	m2	Non-white carbon punch after carbon analysis, indicative of mineral particles in deposit
	m3	A non-typical, but valid, laser response was observed during TOR analysis This phenomena may result in increased uncertainty of the organic/elemental carbon split Total carbon measurements are likely unaffected
n		Foreign substance on sample
	n1	Insects on deposit, removed before analysis
	n2	Insects on deposit, not all removed
	n3	Metallic particles observed on deposit
	n4	Many particles on deposit much larger than cut point of inlet
	n5	Fibers or fuzz on filter
	n6	Oily-looking droplets on filter
	n7	Shiny substance on filter
	n8	Particles on back of filter
	n9	Discoloration on deposit
q		Standard
	q1	Quality control standard
	q2	Externally prepared quality control standard
	q3	Second type of externally prepared quality control standard
	q4	Calibration standard
r		Replicate analysis
	r1	First replicate analysis on the same analyzer
	r2	Second replicate analysis on the same analyzer
	r3	Third replicate analysis on the same analyzer
	r4	Sample re-analysis
	r5	Replicate on different analyzer
	r6	Sample re-extraction and re-analysis
	r7	Sample re-analyzed with same result, original value used
s		Suspect analysis result
v		Invalid (void) analysis result
	v1	Quality control standard check exceeded ±10% of specified concentration range
	v2	Replicate analysis failed acceptable limit specified in SOP
	v3	Potential contamination
	v4	Concentration out of expected range

Table
Chemical Analysis Data Validation Flags[a] (Continued)

Validation Flag	Sub Flag	Description
w		Wet Sample
	w1	Deposit spotted from water drops

[a] Analysis results are categorized as valid, suspect, or invalid Unflagged samples, or samples with any flag except 's' or 'v' indicate valid results The 's' flag indicates results of suspect validity The 'v' flag indicates invalid analysis results Chemical analysis data validation flags are all lower case

Table B-2 Summary of Blank Filter Test Results

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPA
12003	0012003	CB-1/Field Blank	4/7/00		1018 90	127 60	12 80	26 90	1031 80	141 90	406 0
12004	0012004	CB-2/Field Blank	4/7/00		859 50	123 00	0 00	25 70	859 50	137 20	406 0
12009	0012009	CB-3/Field Blank	4/8/00		694 70	119 00	0 00	25 70	694 70	133 40	406 0
12010	0012010	CB-3/Field Blank	4/8/00		782 20	121 00	0 00	25 70	782 20	135 30	406 0
12014	0012014	CB-4/Field Blank	4/9/00		860 80	123 10	37 50	34 70	898 30	138 20	406 0
12015	0012015	CB 4/Field Blank	4/9/00		1091 20	129 80	92 30	62 90	1183 40	146 60	406 0
12018	0012018	CB-5/Field Blank	4/10/00		802 60	121 50	19 60	28 50	822 20	136 30	406 0
12019	0012019	CB-5/Field Blank	4/10/00		1030 80	127 90	47 80	39 30	1078 60	143 30	406 0
12022	0012022	CB-6/Field Blank	4/11/00		723 40	119 60	0 00	25 70	723 40	134 00	406 0
12023	0012023	CB-6/Field Blank	4/11/00		1031 40	128 00	20 70	28 80	1052 10	142 50	406 0
12025	0012025	CB-6/Field Blank	4/11/00		1275 80	136 10	32 80	32 80	1308 60	150 90	406 0
		Average April Field Blank			**924 66**		**23 95**		**948 62**		
12030	0012030	CB-7&8/Field Blank	5/2/00		750 60	120 30	5 20	25 90	755 80	134 70	406 0
12031	0012031	CB-7&8/Field Blank	5/2/00		696 50	119 00	0 00	25 70	696 50	133 40	406 0
12034	0012034	CB-9/Field Blank	5/3/00		837 90	122 50	114 50	75 80	952 40	139 70	406 0
		Average May Field Blank			**761 67**		**39 90**		**801 57**		
12046	0012046	CB-10&11/Field Blank	6/21/00		1430 90	141 90	0 00	25 70	1430 90	155 30	406 0
12050	0012050	CB-12/Field Blank	6/22/00		1237 60	134 80	166 40	106 70	1403 90	154 30	406 0
12052	0012052	CB-12&13/Field Blank	6/22/00		1325 60	137 90	31 60	32 40	1357 20	152 60	406 0
12058	0012058	CB-14&15/Field Blank	6/23/00		1098 30	130 10	0 00	25 70	1098 30	143 90	406 0
12059	0012059	CB-14&15/Field Blank	6/23/00		1461 70	143 10	0 00	25 70	1461 70	156 50	406 0
12060	0012060	CB-14&15/Field Blank	6/23/00		807 20	121 70	0 00	25 70	807 20	135 90	406 0
12061	0012061	CB-14&15/Field Blank	6/23/00		909 50	124 40	4 80	25 90	914 30	138 60	406 0
12062	0012062	CB-14&15/Field Blank	6/23/00		1224 10	134 30	171 80	110 00	1395 90	154 00	406 0
		Average June Field Blank			**1181 54**		**28 97**		**1210 50**		
		Average Field Blank			**997 78**		**34 45**		**1032 22**		

Table B-2. Summary of Blank Filter Test Results (Continued)

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPA
12012	0012012	Carbon Analysis Blank	Apr Test Period		927 80	124 90	1 40	25 70	929 20	139 00	406 0
12024	0012024	Carbon Analysis Blank	Apr Test Period		1057 90	128 80	13 00	27 00	1070 90	143 10	406 0
		Average April Lab Blank			**992 85**		**7 20**		**1000 05**		
12035	0012035	Carbon Analysis Blank	May Test Period		739 40	120 00	38 20	35 00	777 60	135 20	406 0
12037	0012037	Carbon Analysis Blank	May Test Period		963 70	125 90	204 10	129 60	1167 70	146 10	406 0
12040	0012040	Carbon Analysis Blank	May Test Period		2231 20	177 00	334 10	34 20	2565 30	206 00	406 0
		Average May Lab Blank			**1311 43**		**192 13**		**1503 53**		
12047	0012047	Carbon Analysis Blank	Jun Test Period		2275 70	179 10	332 60	34 10	2608 40	208 20	406 0
12051	0012051	Carbon Analysis Blank	Jun Test Period		1139 10	131 40	125 50	82 20	1264 60	149 40	406 0
12063	0012063	Carbon Analysis Blank	Jun Test Period		651 10	118 00	0 00	25 70	651 10	132 50	406 0
		Average Jun Lab Blank			**1355 30**		**152 70**		**1508 03**		
12074	0012074	Carbon Analysis Blank	Extra		1058 70	128 80	0 00	25 70	1058 70	142 70	406 0
12075	0012075	Carbon Analysis Blank	Extra		1063 70	129 00	15 50	27 50	1079 30	143 40	406 0
12076	0012076	Carbon Analysis Blank	Extra		2177 20	174 40	140 20	91 00	2317 50	193 80	406 0
		Average Lab Blank			**1298 68**		**109 51**		**1408 21**		
		AVERAGE BLANK			**1098 08**		**59 47**		**1157 55**		

Comments

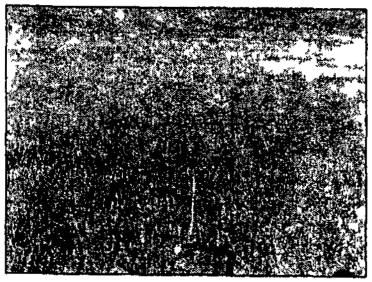
Lab blanks appear to have higher carbon concentrations than field blanks
Lab blanks stored in freezer after weighing, while field blanks taken to field
Organic carbon is 15 x higher than elemental carbon on blank filters, indicating absorption of VOCs
Grassy area tests (CB-4, 5, and 6) showed very little elemental carbon in emissions
First set of burned area tests (CB-1, 2, and 3) showed clear evidence of carbon emissions
Organic and elemental carbon emissions were approximately equal on tests CB-1, 2, and 3

Appendix C

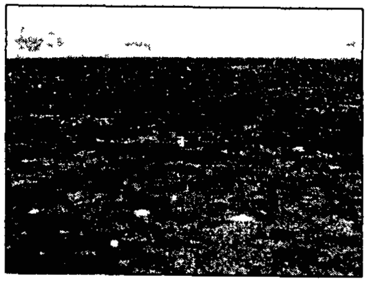
Time Series Photos of Prescribed Burn Area

Time Series of 2000 Prescribed Burn Area at Rocky Flats Environmental Technology Site

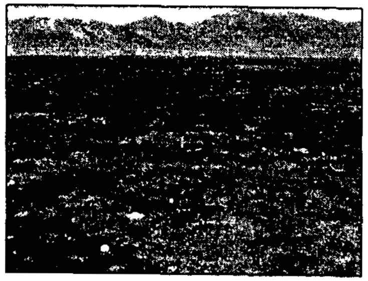
Prescribed Burn Conducted on April 6, 2000



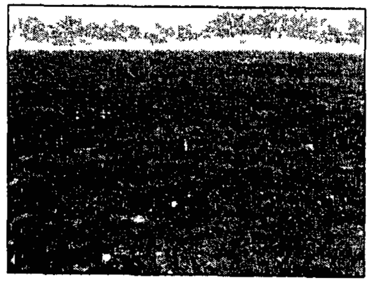
9/15/99



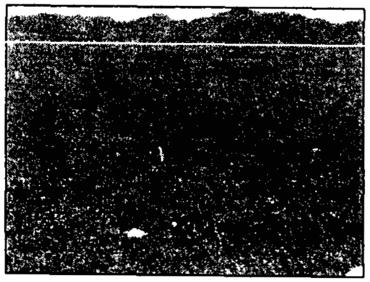
4/7/00



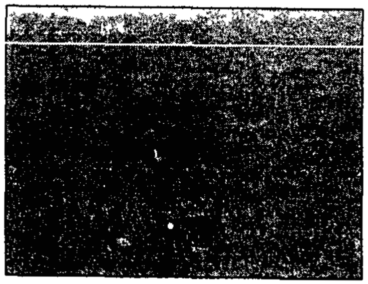
4/17/00



4/27/00

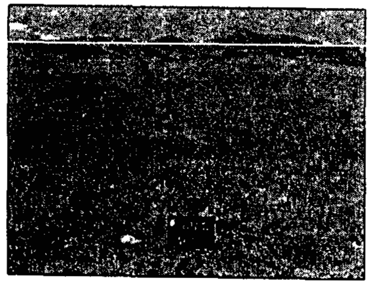


5/22/00



6/28/00

8/10/00



9/27/00

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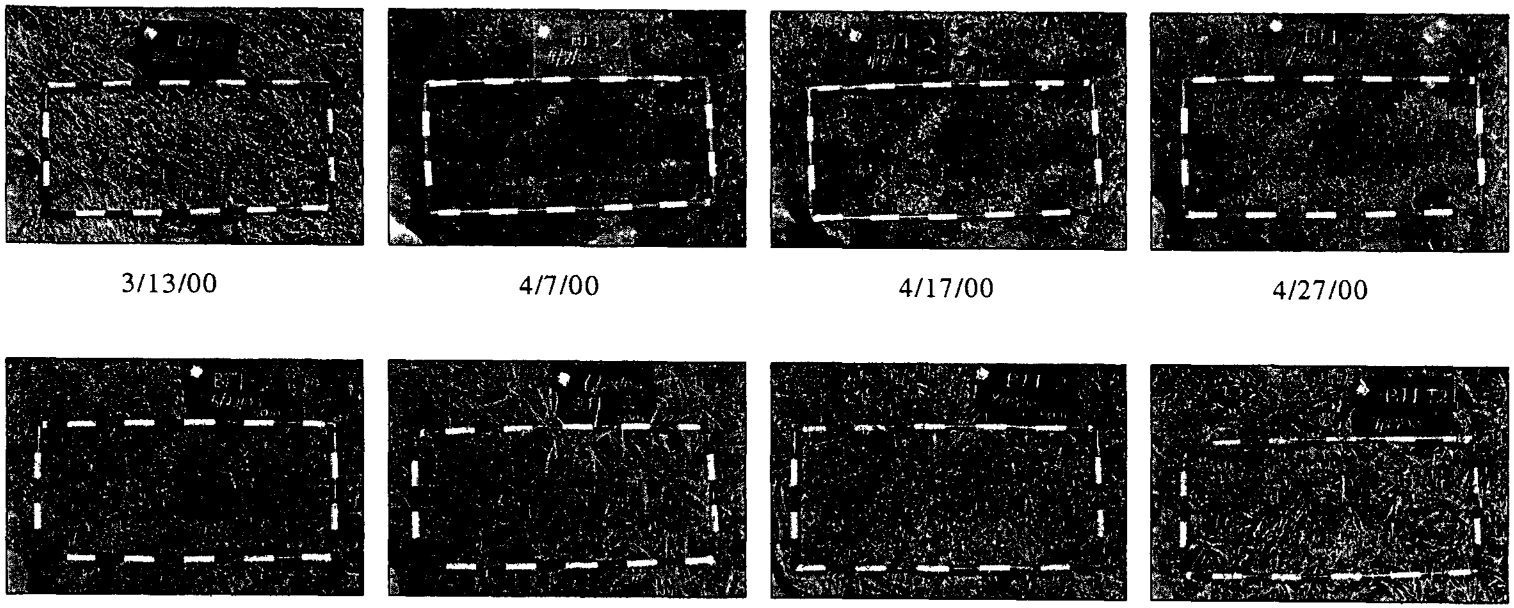
Time Series of Ground Surface in 2000 Prescribed Burn Area at Rocky Flats Environmental Technology Site

Prescribed Burn Conducted on April 6, 2000



3/13/00 4/7/00 4/17/00 4/27/00

5/22/00 6/28/00 8/10/00 9/27/00

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Appendix D

Example Calculation for Run CB-7

CB-7 EXAMPLE CALCULATION

Part I Calculation of tunnel effluent concentrations

- Duration of testing
  CB-7A = 30 min
  CB-7B = 27 min
  CB-7C = 37 min
  CB-7 = 94 min

- Blank-corrected backup filter net weight
  Tare weight = 3293 05 mg
  Final weight = 3302 20 mg
  Blank correction = 0 00 mg
  Filter net weight = 9 15 mg
  *Net weight constitutes PM-10 mass collected by effluent sampler

- Cyclone flow rate = 40 cfm = 68 m^3/h = 1 13 m^3/min

Average effluent PM-10 concentration

$$\frac{9\ 15\ \text{mg}}{1\ 13\ \text{m}^3/\text{min} \times 94\ \text{min}} = 0\ 085\ \text{mg/m}^3$$

- Blank-corrected background filter net weight
  Tare weight = 3300 20 mg
  Final weight = 3319 80 mg
  Blank correction = 0 00 mg
  Filter net weight = 19 60 mg
  *Half of net weight assumed to be PM-10 mass collected from ambient air
  PM-10 mass collected = 9 80 mg

- Duration of background sampling = 217 min
- Cyclone flow rate = 40 cfm = 68 m^3/h = 1 13 m^3/min

Background PM-10 concentration

$$\frac{9\ 80\ \text{mg}}{1\ 13\ \text{m}^3/\text{min} \times 217\ \text{min}} = 0\ 040\ \text{mg/m}^3$$

Net PM-10 Concentration (attributable to emissions from test area)

$0\ 085\ mg/m^3 - 0\ 040\ mg/m^3 = 0\ 045\ mg/m^3$

- Cyclone catch
  Bag tare weight = 3 6875 g
  Bag final weight = 3 7259 g
  Bag net weight = 0 0384 g = 38 4 mg
  *Sample collected in bag represents suspended particles greater than 10 µm aerodynamic diameter

Average effluent TP concentration

$$\frac{9\ 15\ mg + 38\ 4\ mg}{1\ 13\ m^3/min \times 94\ min} = 0\ 448\ mg/m^3$$

Part II Calculation of erosion potentials

- Average maximum Δp at tunnel centerline (CL) during test runs
  CB-7A = 0 49 in H_2O
  CB-7B = 0 49 in H_2O
  CB-7C = 0 64 in H_2O
  CB-7 = 0 54 in H_2O

- Factor conversion of Δp to wind speed (mph)
  Average barometric pressure = 24 3 in Hg
  Ambient temperature = 65°F

$$K' = 10\ 83 \times \left(\frac{(65°F + 459\ 3)}{24\ 3\ in\ Hg} \right)^{1/2} = 50\ 305$$

Maximum wind speed (mph) at tunnel CL

$$50\ 305 \times (0\ 54\ in\ H_2O)^{1/2} = 37\ 0\ mph$$

- Average surface roughness height for test period

CB-7A	=	0 90 cm	CB-8A	=	1 20 cm	CB-9A	=	1 73 cm
CB-7B	=	1 22 cm	CB-8B	=	1 20 cm	CB-9B	=	1 42 cm
CB-7C	=	1 19 cm	CB-8C	=	1 52 cm	CB-9C	=	1 57 cm
CB-7	=	1 10 cm	CB-8	=	1 31 cm	CB-9	=	1 57 cm

  Average roughness height = 1 33 cm

- Tunnel CL height = 15 2 cm

Equivalent maximum wind speed (mph) at 10-m height

$$\frac{37\ 0\ mph \times \ln \dfrac{1000\ cm}{1\ 33\ cm}}{\ln \dfrac{15\ 2\ cm}{1\ 33\ cm}} = 100\ 6\ mph$$

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Corresponding friction velocity

$$\frac{37.0 \text{ mph} \times 0.4}{\ln \dfrac{15.2 \text{ cm}}{1.33 \text{ cm}}} = 6.08 \text{ mph} = 271.8 \text{ cm/s}$$

- Net PM-10 mass collected

$$9.15 \text{ mg} - (9.80 \text{ mg} \times \frac{94 \text{ min}}{217 \text{ min}}) = 4.90 \text{ mg} = 0.00490 \text{ g}$$

 *Background mass time-weighted to emission sampler run time

- Ratio of sampling extension area to inlet nozzle area
  Sampling extension i d = 7.874 in — Sampling extension area = 48.69 in^2
  Intake nozzle i d = 0.88 in — Intake nozzle area = 0.608 in^2
  Ratio = 80.08

- Area of ground surface sampled = 0.918 m^2

PM-10 erosion potential/loss

$$\frac{0.00490 \text{ g} \times (80.08 \times 85\%)}{3 \times 0.918 \text{ m}^2} = 0.12 \text{ g/m}^2$$

*Three tests areas sampled during CB-7
*85% of the centerline wind speed is the average wind speed over the area of the sampling extension

TP erosion potential/loss

$$\frac{(0.00490 \text{ g} + 0.0384 \text{ g}) \times (80.08 \times 85\%)}{3 \times 0.918 \text{ m}^2} = 1.07 \text{ g/m}^2$$

*Three tests areas sampled during CB-7
*85% of the centerline wind speed is the average wind speed over the area of the sampling extension

Part III Calculation of carbon contribution to PM-10 mass

- Emission sampler filter
  PM-10 mass collected = 9 15 mg
  Organic carbon = 3011 00 μg/filter
  Elemental carbon = 829 00 μg/filter
  Sampling duration = 94 min

- Background filter
  PM-10 mass collected = 9 80 mg
  Organic carbon = 4505 30 μg/filter
  Elemental carbon = 468 30 μg/filter
  Sampling duration = 217 min

- Average blank filter
  Organic carbon = 1098 08 μg/filter
  Elemental carbon = 59 47 μg/filter

Emission sampler blank-corrected organic carbon

3011 00 μg/filter – 1098 08 μg/filter = 1912 92 μg/filter
*Organic carbon contributed to PM-10 mass on filter

Emission sampler blank-corrected elemental carbon

829 00 μg/filter – 59 47 μg/filter = 769 53 μg/filter
*Elemental carbon contributed to PM-10 mass on filter

Adjusted background sampler net mass

$$9\ 80\ \text{mg} \times \frac{94\ \text{min}}{217\ \text{min}} = 4\ 25\ \text{mg}$$

*Background mass time-weighted to emission sampler run time

Background sampler blank corrected organic carbon

4505 30 μg/filter – 1098 08 μg/filter = 3407 22 μg/filter

Adjusted background sampler blank corrected organic carbon

$$3407\ 22\ \mu\text{g/filter} \times 50\% \times \frac{94\ \text{min}}{217\ \text{min}} = 737\ 97\ \mu\text{g/filter}$$

*Half of net carbon collected on filter assumed to be PM-10
*Background mass time-weighted to emission sampler run time

Background sampler blank corrected elemental carbon

468 30 μg/filter – 59 47 μg/filter = 408 83 μg/filter

Adjusted background sampler blank corrected elemental carbon

$$408\ 83\ \mu g/\text{filter} \times 50\% \times \frac{94\ \text{min}}{217\ \text{min}} = 88\ 55\ \mu g/\text{filter}$$

*Half of net carbon collected on filter assumed to be PM-10
*Background mass time-weighted to emission sampler run time

Net PM-10 mass

9 15 mg – 4 25 mg = 4 9 mg

Net organic carbon

1912 92 μg/filter - 737 97 μg/filter = 1174 95 μg/filter

1 17 mg organic carbon in PM-10 mass

Net elemental carbon

769 53 μg/filter - 88 55 μg/filter = 680 98 μg/filter

0 68 mg elemental carbon in PM-10 mass

Net total carbon

1 17 mg organic + 0 68 mg elemental = 1 85 mg